M.O. 501 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 77. No. 917. NOVEMBER 1948

METEOROLOGICAL RESEARCH FLIGHT

BY RONALD FRITH, M.A., Ph.D.

From the time, a century or two ago, of the earliest meteorological measurements in the free air, our knowledge of conditions in the troposphere and lower stratosphere has increased, at varying rates, through observations obtained from manned balloons, kites, sounding balloons, pilot balloons and, within about the last 30 years, aircraft and radio-sondes. Before 1939, the number of routine soundings enabled upper air pressure and temperature charts to be prepared regularly for certain areas. The years of war saw a greatly increased use of radio-sondes for determination of temperature and humidity to heights in excess of normal aircraft ceiling, and the introduction and extended use of radio and radar methods for wind measurements.

Nevertheless the information obtained, whether from aircraft or radio-sonde, was far from complete. For example, humidity measurements, except at comparatively high temperatures, were either lacking or inaccurate. The presence of cloud, and its type, could be reported from an aircraft, but no measurements could be made of its density (liquid or solid content) or the number and size of its particles.

It was believed that knowledge of these quantities would not only benefit the general science of meteorology, but would be of great value in connexion with two special problems thrown into prominence by the war—icing and condensation trails.

So, in 1942, it was arranged that the High Altitude Flight at Boscombe Down should give facilities for meteorological investigations to be carried out by meteorologists in aircraft. The initial objective was the improvement of existing aircraft meteorological instruments and the development of new ones. It was expected that in the course of this work the research unit would accumulate valuable meteorological data. This expectation has been justified.

Early work.—*Temperature measurements* made from aircraft require correction for the speed of the aircraft. With fast, high-flying aircraft this correction is very large (in excess of 20°F.). It had been realised for some time that existing determinations of the " speed correction coefficient " were not sufficiently accurate, so one of the first tasks imposed on this new unit was to

measure these coefficients and to assist the Instruments Division of the Meteorological Office in the design and development of new thermometers.

Many types of thermometer were tested and eventually a completely new, distant-reading, electrical instrument was developed. This, the flat-plate electrical thermometer, is rapid in response and very accurate. It is suitable for all types of aircraft, including single-seater single-engined types, and is now widely used.

Humidity measurements.—Rapid progress was also made by Dr. G. M. B. Dobson of Oxford University in association with Mr. A. W. Brewer, the Meteorological Officer of the flying research unit, in the development of an aircraft frost-point hygrometer.

At this time there were two standard ways of measuring the humidity in the upper air—(i) the wet- and dry-bulb psychrometer; (ii) hygrometers using some substance responsive to changes in humidity (hair, goldbeater's skin, etc.). Both of these, satisfactory enough at moderate or high absolute humidities, fail completely at low absolute humidities. It was hoped that a frost-point hygrometer would work down to the lowest humidities likely to be found within the range of present-day aircraft. This proved to be the case, and on December 22, 1943, the new instrument was used on an ascent which penetrated the stratosphere. Fig. 1 shows the results of this sounding. These are believed to be the first reliable measurements of humidity ever made in the stratosphere. Since then some 50 similar ascents have been made.

At low levels too, the instrument gave information of great interest. Frost points as low as −50°F. and relative humidities of less than 1 per cent. were found to be not uncommon in subsided air.

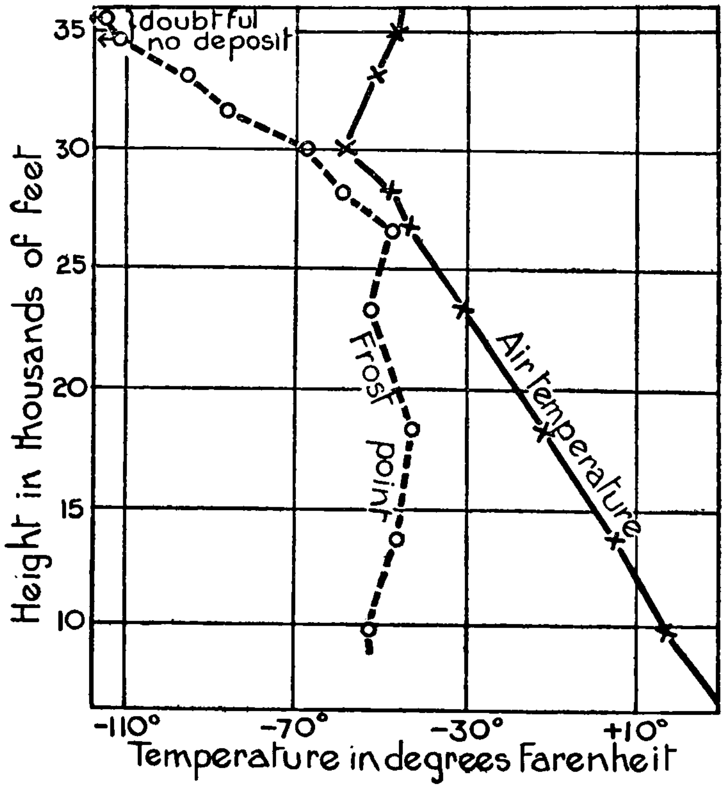

FIG. 1—THE FIRST ASCENT WHEN HUMIDITIES WERE MEASURED IN THE STRATOSPHERE
Boscombe Down, December 22, 1943

In 1946 the research unit was transferred to the Royal Aircraft Establishment at South Farnborough, re-equipped with two Halifax and two Mosquito aircraft, and renamed the Meteorological Research Flight.

Meteorological Research Flight.—Although the flight is still very much concerned with the development of aircraft meteorological instruments, a regular part of the work now consists in the use of instruments previously developed, either here or elsewhere, for the study of the atmosphere.

High-level and high-speed work.—About 10 ascents into the stratosphere, using Mosquito aircraft, are aimed at each month. The ascents generally reach 39,000 or 40,000 ft. and take about 1¼ hr.

Especially since the installation of remote-controlled frost-point hygrometers, in which the frost is " seen " photo-electrically, these trips (if nothing goes wrong) can be quite pleasant.

It is also planned to use these aircraft to assist in the development of totally different methods of measuring humidity at very high levels.

Apart from this humidity work, Mosquito aircraft are also used to check the air-temperature speed corrections at high speeds, and at high levels. This work is tiring. It entails flying, generally at 30,000 ft., to and fro, in the same air as near as can be determined, and at various speeds. A complete run consists of eight legs, on each of which the aircraft is flown steadily for a minute or two at each of the following speeds: 220, 240...360 m.p.h. Such a run takes about 2½ hr. But so variable are the air temperatures that the means of the eight readings obtained at each speed still do not lie smoothly on a curve; and a great many similar runs are required before a firm value for the speed correction coefficient can be found.

Medium- and low-level work.—The Halifax aircraft are used for work up to 20,000 ft. This consists mainly of:—

(*a*) A study of the " fine " structure of the atmosphere. This work is of importance, for example, in connexion with turbulence and generally atmospheric stability.

(*b*) A study of the structure of clouds and of the development of rain.

For some time work under (*a*) consisted mainly of detailed readings of temperature and humidity during a slow ascent or descent. These readings appeared to show that " subsidence inversions " were very common, and very complex. However it has been lately realised that variations in the horizontal also are often quite large, and special attention is now being given to mapping temperature and humidity over horizontal areas, generally of about 30 mi. × 20 mi. Fig. 2 shows such a map.

It takes 2–2½ hr. to make a survey of this size and requires at least three observers—one to operate the frost-point hygrometer, one to operate the electrical thermometer and the third to take readings of airspeed, height, position, etc. If possible, a fourth observer makes independent temperature readings.

A number of these surveys have now been made under widely differing synoptic situations. Broadly speaking they show temperature and humidity patterns, generally closed, on a scale measured in tens of miles, with a temperature range of about 1°F. and a frost-point range of 10–20°F. or even more.

The frost-point and temperature isopleths are generally similar, dry air being warm, and moist air cold.

Item (*b*), the study of the structure of clouds and of the development of rain, is perhaps the most interesting of all our work. It is certainly the most difficult. It involves:—

(i) The measurement of the numbers and sizes of cloud particles and of rain drops.

(ii) The recognition of ice crystals as distinct from water droplets in a cloud.

(iii) The study of where and how rain develops.

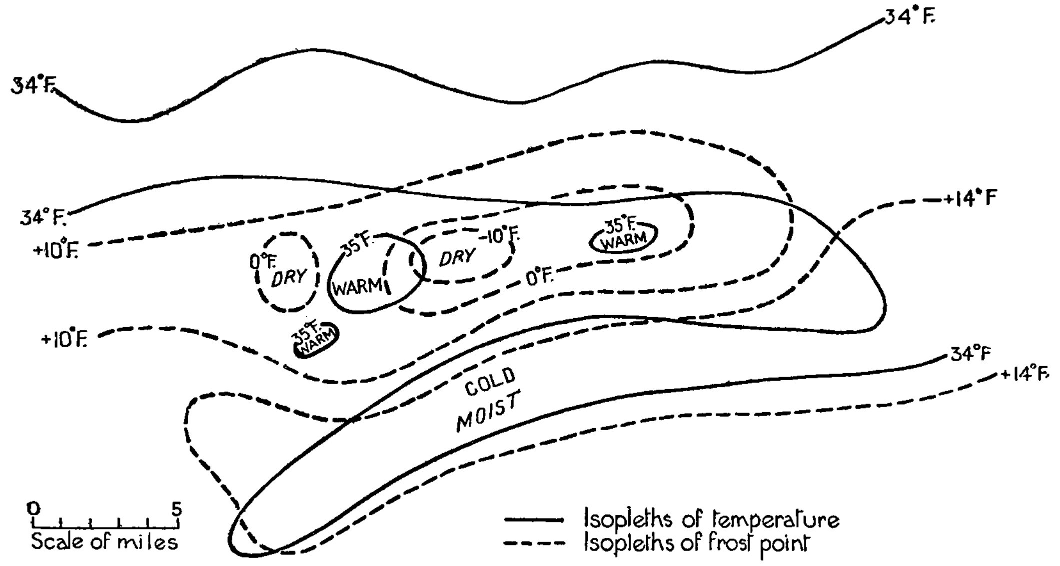

FIG. 2—ISOPLETHS OF FROST POINT AND TEMPERATURE AT 10,000 FT. OVER SOUTH MIDLANDS, APRIL 27, 1948

At present qualitative measurements are obtained of the sizes and the numbers of cloud particles by exposing in the cloud for a short period (1/100 sec.) a microscope slide in a suitably designed container. The slide is coated with soot, magnesium oxide or a green gelatine film. Using any of these coatings each cloud particle which strikes the slide leaves a pit or stain. By examining the slide under a microscope, counting and measuring the pits or stains, a qualitative picture of the size distribution is obtained and thus of the water content in the cloud. Figs. 3 and 4 (facing p. 252) show a typical slide magnified 100 times and work in progress in the aircraft.

Ice crystals leave an irregular pit on the soot- or magnesium-oxide-coated slides and can thus be recognised.

Other instruments are in course of development which will make similar measurements either photographically or, in supercooled clouds, by measuring the rate of ice formation on rods of different diameters.

Work is also progressing, in co-operation with the Instruments Division of the Meteorological Office, on apparatus, suitable for use in aircraft, for measuring the sizes of drizzle and rain drops.

The formation of rain is studied in two ways; first, by making ascents through warm-front cloud systems, and observing visually and instrumentally all that is to be observed, and secondly, by studying the development of cumulus clouds as they grow into shower clouds.

The study of the development of cumulus clouds has presented a quite unforeseen difficulty in the rapidity with which these clouds grow and decay, so that a promising-looking cloud, by the time one has reached it, is either a fully developed cumulonimbus, or else has practically disappeared. In this way one can fly about from cloud to cloud for hours without ever being present when a cumulus cloud begins to precipitate.

Ground work.—In the preceding sections stress has largely been laid on work in the air. On the ground there is, on the one hand, a good deal of work to be done in measuring and counting, in computing and tabulating; and, on the other, there are always past results to study, to write up and, if possible, to explain.

For the instrument-development work the flight has its own workshop, and employs an instrument maker.

So, whether it is a " flying day " or not, there is always plenty of interesting work to be done, and, perchance, new discoveries to be made.

CALCULATION OF THE RELATIVE HUMIDITY WHEN THE AIR TEMPERATURE IS BELOW 32°F.

BY R. H. COLLINGBOURNE, M.SC.

The relative humidity, U, is defined* by the relation $U = 100\ r/r_w$ where r is the mixing ratio of the air and r_w is the saturation mixing ratio at the same temperature and pressure. This is, however, for most practical purposes, equivalent to

$$U = 100\ e'/e'_w$$

where e' is the vapour pressure of the air and e'_w is the saturation vapour pressure at the temperature of the air T. When, however, the air temperature is below 32°F. the saturation vapour pressure has two possible values, the saturation vapour pressure over ice and the saturation vapour pressure over supercooled water. There are therefore two values of the relative humidity under these conditions and a convention has to be adopted as to which is used. The present Meteorological Office practice is to calculate the relative humidity with reference to saturation over ice, but it is proposed that, after January 1, 1949, in accordance with a resolution passed by the Conference of Directors in 1947, the relative humidity shall be calculated with reference to saturation over liquid water at all temperatures. The revised definition will give lower values of the relative humidity at temperatures below 32°F. It is the purpose of this note to show what changes will be necessary in the present method of using the Bilham humidity slide-rule to calculate the relative humidity.

The humidity slide-rule, designed by E. G. Bilham†, is used at most Meteorological Office stations. The instrument, at present in use, is designated the Mk. II and differs in a number of points from that originally described by Bilham, which is now called the Mk. I. In the Mk. II (illustrated facing p. 253), scale 4, on the upper edge of the slide, is a scale of temperature such that the distance of any graduation mark, T, from a certain fixed point is

---

*I.M.O. Conference of Directors, Washington, D.C., Resolution 166, 1947.

†BILHAM, E. G.; A slide-rule for hygrometric calculations. *Met. Mag., London,* **70**, 1935, p. 254.